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NORMAL CONTRAST SENSITIVITY IN 200 CHILDREN AGED SEVEN TO 13 YEARS

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Abstract

The Vistech VCTS 6000 and 6500 tests are designed to accurately assess contrast sensitivity under a specified illumination. A normal range of contrast sensitivities was provided by Vistech for both tests based on results from 300 subjects ranging in age from 10 to 70 years. As contrast sensitivity varies with age it was hypothesised that the normals given may not have accurately reflected contrast sensitivity for children. Two hundred children between the ages of seven and 13 years (with 6/6, N5 vision and no strabismus) were assessed with both tests. Results show that subjects in this age group are more sensitive to low contrast for high spatial frequency gratings than the test normals suggested.

Key words: *Contrast sensitivity, Vistech chart, normals, children, CSF.*

INTRODUCTION

As objects in the visual world are not usually made up of black outlines on a white background like letters on a conventional visual acuity chart, visual acuity measurement tells the examiner nothing about the visibility of objects larger or smaller than the letters on the chart or objects that are not 100% contrast. As a result contrast sensitivity tests are being used to assess the ability to recognise subtle shadings on low contrast backgrounds. As the targets (gratings) vary in size and orientation and in the number of repeats of the pattern (spatial frequency) as well as contrast, much more information can be gained about visual capabilities.

Contrast refers to the differences between the maximum and minimum luminance of the grating. It is defined by Michelson as

$$c = (L_{max} - L_{min})/(L_{max} + L_{min})$$

where c is contrast, L_{max} is maximum luminance and L_{min} is minimum luminance. Michelson contrast ranges from zero (no contrast) to one (100% contrast or black on white).[1]

Contrast sensitivity at high spatial frequency (narrow gratings) is needed to see fine detail and small print and it has been demonstrated that high spatial frequency resolution is related to above average Snellen acuity. Low and middle spatial frequencies have been correlated with the ability to see large low contrast targets. Recognition of human faces depends heavily on low spatial frequencies.[2-4] Patients with defective low to middle contrast sensitivity and normal high contrast sensitivity can therefore see the bottom line of a vision chart (which indicates normal vision) but may not see large objects on a low contrast background.

Assessment of contrast sensitivity is an important diagnostic tool for assessing visual deficit in a number of conditions. These include amblyopia[5-7] refractive error and astigmatism,[8] glaucoma,[9] cataract,[10] macular disease,[11]

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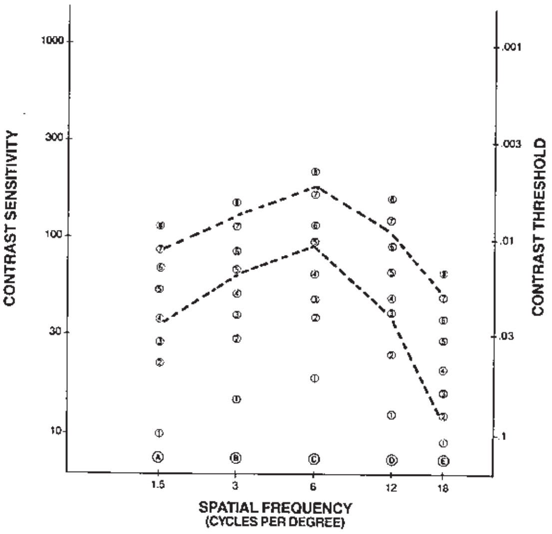

Figure 1: VCTS evaluation form (reproduced with permission from Vistech Inc).

multiple sclerosis[12] and optic neuritis,[13] corneal oedema[14] and cerebral lesions.[15]

There are a number of different techniques available for the assessment of contrast sensitivity, the most recently introduced are the printed photographic test stimuli. These techniques are cheaper and quicker to administer and simpler to design than the tests that use visual display unit (VDU) stimulation.

The first of the printed photographic tests was developed by Arden and produced by the American Optical Company and were therefore known as the AO plates. Many investigators have criticised the AO plates because they were designed for screening thus they only tested up to 6.2 cycles per degree. In order to test contrast sensitivity in patients with vision that ranged from normal to near blindness, stimulus contrasts that ranged from near normal threshold values (0.003) to a maximum of 1.00 were needed. As the contrast range did not extend to the very high spatial frequencies many patients with visual problems performed normally on the AO plates.[16]

Ginsburg[17] (1984) developed a set of plates known as the Vistech VCTS system. The Vistech VCTS 6000 and 6500 contrast sensitivity tests measure the subjects ability to detect bands or gratings of various spatial frequencies and different contrasts under specified illumination at 1/3 m and 3.05 m, respectively. The minimum contrast at which the grating can be seen is known as the contrast threshold and contrast sensitivity is the reciprocal of the contrast threshold.

The Vistech tests come with evaluation forms (see Figure 1) and an overlay (represented by dotted lines) showing the normal range of contrast sensitivity in patients tested binocularly.[18] This normal range is based on a sample of 300 people ranging from 10 to 70 years of age measured under specific luminance conditions.[19,20] (For each row the mean was assessed and the upper and lower boundaries of the normal range represented the 5th and 95th percentiles.)[18] According to the Vistech manuals the contrast sensitivity of normal individuals age 50 years and younger with no visual complaints, should fall in the upper half of the normal range.[19,20]

Many authors have demonstrated that contrast sensitivity increases throughout childhood then decreases with old age; mostly at mid and high spatial frequencies.[4,21-30] Another author suggested that contrast sensitivity did not alter with age.[31]

Diagnosis of reduced sensitivity in the Vistech tests is based on the lower limit of the normal range as indicated by the overlay. As the age range that these normals were based on was a predominantly older population that varied greatly in age it was considered that the Vistech normals may not accurately reflect the normal contrast sensitivity for school children between the ages of seven and 13 years. This paper reported the findings of contrast sensitivity using the VCTS 6000 and 6500 on 200 children in that age range.

METHOD

Two hundred and twenty five children who attended the same primary school were selected to form the normal population. A random computer allocation of the order of all testing procedure was done for all 225 children, with each child being issued with a case number as they came into the room for testing. Classes were selected at random throughout the testing time.

Visual acuity assessment, cover test and Lang stereo tests were performed in random order on each child. Of the 225 children, 200 had monocular visual acuity of 6/6 (Snellen's linear chart), N5 (reading chart) with each eye without optical correction and no strabismus, and were thus included in the study group to have their contrast sensitivity tested. The mean age of the children was 10.34 years and none of the children had had previous exposure to the tests.

Contrast sensitivity testing procedures were exactly the same as those used by Vistech.[19,20] The order of testing (ie VCTS 6000 or VCTS 6500 performed first) was randomised. Both tests were conducted binocularly using uniform and constant illumination between 30-50 ft-L. Light intensity readings from one area of the chart to another and from the VCTS 6000 to the VCTS 6500 were within 5° of pointer movement of this range. As long as the readings were in this range, results could be compared with the Vistech population normals.

Both Vistech tests had 40 sine wave grating targets. Each target consisted of a number of bands (sine waves) which either pointed upwards (0°) or were tilted 15° to the right or left of the vertical position. Subjects were asked to identify the orientation of the bands in each target they could see in each row in turn. The orientation of the bands was randomised along each row to help control for guessing. The mean luminance of the targets was 90 cd/m² and the mean luminance of the surround was 125 cd/m².

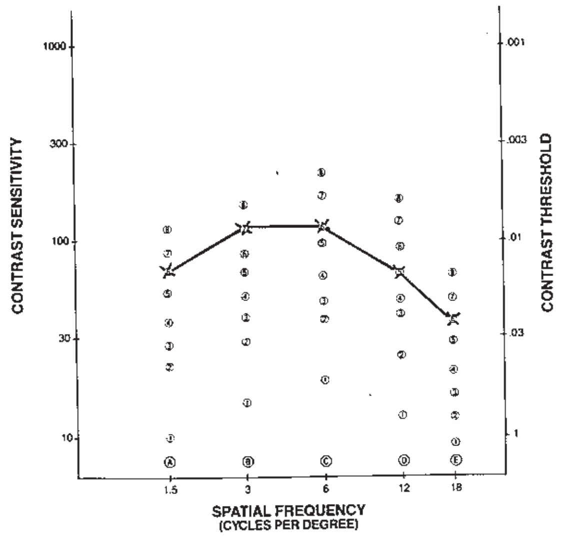

Figure 2: VCTS evaluation form showing normal CSF curve.

The targets were divided into rows A, B, C, D and E each consisting of eight targets. All the targets in a given row had the same spatial frequency (band width) and a different contrast. The spatial frequencies were row A; 1.5 cycles/degree, row B; 3 cycles/degree, row C; 6 cycles/degree, row D; 12 cycles/degree and row E; 18 cycles/degree.

The highest contrast targets (with a contrast threshold of 0.1) were found at the left hand end of each row (in column 1). Targets became progressively lower in contrast across to the right of the chart. In each row targets were numbered one to nine with the lowest contrast targets being in column eight. In column nine there were no bands.

Results of each test were recorded on Vistech contrast sensitivity evaluation forms with the target number marked with "x" in each column corresponding to the lowest contrast target orientation correctly identified by the subject in each row. The "x's" were connected by a line forming a curve known as the contrast sensitivity function (CSF) curve (see Figure 2). The curve was the graphic representation of spatial contrast sensitivity as a function of the spatial frequency of the gratings. On the evaluation forms the horizontal axis represented spatial frequency with the lowest spatial frequency row (row A) being on the left hand end of the axis. The vertical scale on the left gave the log of the contrast sensitivity. The vertical scale on the right gave the log of contrast threshold (one/contrast sensitivity).

To be able to directly compare the results of the contrast sensitivity tests to the Vistech norms the normal range was assessed using percentiles. The 5th and 95th percentiles were calculated for each row of the tests.[32]

The null hypotheses were that the CSF curve would not be affected by whether the child was

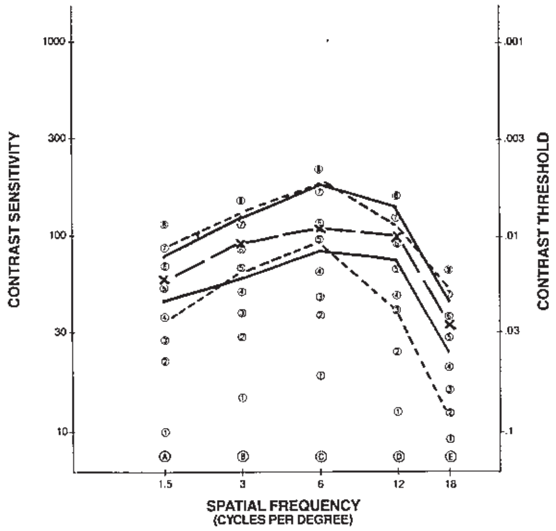

Figure 3a: Normal contrast sensitivity function curve, 5th and 95th percentiles (black lines) for children aged seven to 13 years for VCTS 6500 (3.05 m).

------- VCTS Normal limits
——— Normal limits seven to 13 years
X Mean scores
X--X--X CSF curve

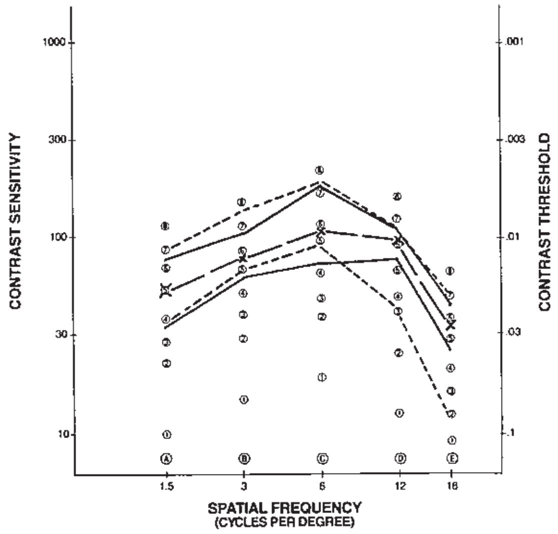

Figure 3b: Normal contrast sensitivity function curve, 5th and 95th percentiles (black lines) for children aged seven to 13 years for VCTS 6000 (1/3 m).

------- VCTS normal limits
——— Normal limits seven to 13 years
X Mean scores
X--X--X CSF curve

assessed firstly at near or distance test or by the sex of the child (ie the independent variables).

To ascertain whether these independent variables would effect the scores analysis of variance (ANOVA) was used. This analysis was performed using Statsoft CSS Complete Statistical Package; Statsoft, 1987. The significance level used was 0.05. (If $p<0.05$ then it was not very likely that the result had arisen by chance.)

RESULTS

For every child the minimum contrast seen for each different spatial frequency (that is each different row) was recorded on an evaluation form.

The mean score was calculated for each row as were the 5th and 95th percentiles (see figures 3a and 3b). Scores that fell within this range were considered to be within normal limits (see Tables 1 and 2). From the mean scores a normal contrast sensitivity function curve was constructed. This normal range of scores could be directly compared to the normal ranges of the Vistech form.

These results have clearly demonstrated that for children between the ages of seven and 13 years, contrast sensitivity for high spatial frequencies (narrow bands, rows D and E) was much higher than the range suggested by the Vistech normals. Thus children appreciated these targets at much lower contrasts than was previously realised. As a result the shape of the contrast sensitivity function curve for children differed from the shape of the curve for the 10 to 70 year old subjects tested by Vistech. These findings agreed with the findings reported for 325 children aged six to 12 years.[33]

The normal range for mid spatial frequencies (row C) showed a mixed result. The lower limit of the normal range for both the tests were slightly lower than the Vistech normal range. The upper limit of normal was the same as the Vistech normals.

The maximum sensitivity to contrast (peak contrast) occurred at six cycles per degree for both the VCTS 6000 and the VCTS 6500. This maximum sensitivity is similar to the maximum sensitivity in adults on the VCTS tests.

TABLE 1

Scores, Means and 5th and 95th Percentiles of Cases Achieving Each Score for the VCTS 6500 (3.05 m)

Score*	Row A	Row B	Row C	Row D	Row E
4	3	1	4	0	9
5	134	38	26	22	67
6	53	129	142	134	110
7	10	30	27	42	13
8	0	1	1	2	1
Mean	5.350	6.005	5.975	6.120	5.645
5th percentile	4.6	4.7	4.7	5.1	4.5
95th percentile	6.5	7.2	7.2	7.3	6.9

*Score refers to the target number of the lowest contrast target seen by the subject.

Results in this study were obtained testing subjects binocularly. Ross et al[26] reported only minimal improvement in contrast sensitivity in adults when tested binocularly rather than monocularly.

Analysis of variance revealed that sex had no effect on the score in any of the rows ($p>0.05$) and, in addition, the order of testing had no statistically significant effect on the scores (analysis of variance showed $p>0.05$ in all rows).

DISCUSSION

The study has clearly demonstrated that for children aged between seven and 13 years old, contrast sensitivity to high spatial frequency gratings is much higher than has been previously reported. This finding has been supported by a separate study conducted by the author in which another population of 325 children between the ages of six and 12 years old were assessed.[33]

A number of other studies which have assessed the contrast sensitivity in adults[4,21-30] have demonstrated a higher sensitivity at the high spatial frequencies in young adults.

Using VDU screens, a number of authors have demonstrated an improvement in contrast sensitivity with age.[22,27-30] In the other series of 325 normal children conducted by the author, results demonstrated that contrast sensitivity improved with age up to 10 years old. In this study the effect of age on contrast sensitivity within the study population was not investigated as there was an uneven distribution of cases in each age group.

Arden[31] reported that age does not influence results in a study carried out on patients aged from 11 to 70 years using the AO plates monocularly. Findings from most studies do not agree with Arden's, however, this could be explained by the fact that the AO test only measures contrast at relatively low spatial frequencies from 0.2 up to 6.4 cycles/degree. The Vistech test measured contrast sensitivity with higher spatial frequency gratings (up to 18 cycles per degree). The increased sensitivity in the seven to 13 year age group occurred only in the high spatial frequency gratings which were not used in the AO test.

The peak sensitivity in this study was found to occur at six cycles per degree for both the VCTS 6000 (1/3 m) and the VCTS 6500 test (3.05 m). A similar finding has been reported by

TABLE 2

Scores, Means and 5th and 95th Percentiles of Cases Achieving Each Score for the VCTS 6000 (1/3 m)

Score*	Row A	Row B	Row C	Row D	Row E
4	29	3	13	0	8
5	144	67	62	12	53
6	26	115	102	176	132
7	0	15	22	11	7
8	1	0	1	1	0
Mean	5.00	5.71	5.68	6.005	5.735
5th percentile	3.8	4.6	4.2	5.3	4.6
95th percentile	6.2	6.8	7.1	6.7	6.5

*Score refers to the target number of the lowest contrast target seen by the subject.

several other researchers using the Vistech tests on children and adults.[29,34] However, when using VDU display techniques to assess peak CSF a number of authors[27,35,36] found the peaks occurred at lower spatial frequencies around four cycles per degree.

CONCLUSIONS

The finding of increased contrast sensitivity for narrow stripes in children between the ages of seven and 13 has obvious clinical application. Children who had a low score in the high spatial frequency gratings were previously thought to be within normal limits. Following this study it is apparent that they are not within normal limits. Contrast sensitivity at high spatial frequency (12 to 18 cycles/degree, rows D and E) is affected in a number of conditions commonly affecting children. These include amblyopia, refractive error and astigmatism. As these conditions can cause unnecessary and permanent visual loss it is most important that appropriate norms be used when testing contrast sensitivity in this age group.

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References

1. Legge GE, Rubin GS, Luebker A. Psychophysics of reading. V. The role of contrast sensitivity in normal vision. Vision Res 1987; 27: 1165-1177.
2. Harmon LD. The recognition of faces. Sci Am 1973; 229: 70.
3. Leibowitz H, Post R, Ginsburg AP. The role of fine detail in visually controlled behaviour. Invest Ophthalmol Vis Sci 1980; 19: 846.
4. Owsley C, Sekuler R, Siemens D. Contrast sensitivity throughout adulthood. Vision Res 1983; 23: 689-699.
5. Hess RF, Howell ER. The threshold contrast sensitivity function in strabismic amblyopia; evidence for a two type classification. Vision Res 1977; 17: 1-49-1056.
6. Levi DM, Harwerth RS. Spatio temporal interactions in anisometropic and strabismic amblyopia. Invest Ophthalmol Visual Sci 1977; 16: 90-95.
7. Levi DM, Harwerth RS. Contrast sensitivity in ambylopia due to stimulus deprivation. Br J Ophthalmol 1980; 64: 15-20.
8. Fiorentini A, Maffei L. Spatial contrast sensitivity of myopic subjects. Vision Res 1976; 16: 438-438.
9. Arden GB, Jacobsen J. A simple grating test for contrast sensitivity: preliminary results indicate value for screening in glaucoma. Invest Ophthalmol Vis Sci 1978; 17: 23-32.
10. Hess RF, Woo G. Vision through cataracts. Invest Ophthalmol Vis Sci 1978; 17: 428-435.
11. Sjostrand J, Frisen L. Contrast sensitivity in macular disease. Arch Ophthalmol 1977; 55: 507-514.
12. Regan D, Silver R, Murrary R. Visual acuity and contrast sensitivity in multiple sclerosis-hidden visual loss. Brain 1977; 100: 563-579.
13. Frisen L, Sjostrand J. Contrast sensitivity in optic neuritis: A preliminary report. Doc Ophthalmol Proc 1979; 17: 165-173.
14. Hess RF, Garner LR. The effect of corneal oedema on visual function. Invest Ophthalmol Vis Sci 1977; 16: 5-13.
15. Bodis-Wollner L, Diamond SP. The measurement of spatial contrast sensitivity in cases of blurred vision associated with cerebral lesion. Brain 1976; 99: 695-710.
16. Verbaken JH, Johnston AW. Population norms for edge contrast sensitivity. Am J Optom Physiol Optics 1986, 63: 724-732.
17. Ginsburg AP. A new contrast sensitivity vision test chart. Am J Optom Physiol Optics 1984; 16: 403-407.
18. Whitney Turner M. Personal communication, Vistech Consultants Inc, March, 1988.
19. Vistech Consultants Incorporated. The Vistech 6000 Luminance Considerations. Vistech Inc, 1985.
20. Vistech Consultants Incorporated. The Vistech 6500 Luminance Considerations. Vistech Inc, 1985: 2.
21. Arundale K. An investigation into the variation of human contrast sensitivity with age and ocular pathology. Br J Ophthalmol 1978; 62: 213-215.
22. Derefeldt G, Lennerstrand G, Lundh B. Age variations in normal contrast sensitivity. Acta Ophthalmol (Kbh) 1979; 57: 679-690.
23. Sekuler R, Hutman LP. Spatial vision and aging 1. Contrast sensitivity. J Gerontol 1980; 35: 692-695.
24. McGrath C, Morrison JD. The effects of age on spatial frequency perception in human subjects. QJ Exp Physiol 1981; 66: 253-261.
25. Skalka HW. Effect of aging on Arden grating acuity. Br J Ophthalmol 1980; 64: 21-23.
26. Ross JE, Clarke DD, Bron AJ. Effect of age on contrast sensitivity function: Uniocular and binolcular findings. Br J Ophthalmol 1985; 69: 51-56.
27. Beazley LD, Illingworth DJ, Jhan A, Greer DV. Contrast sensitivity in children and adults. Br J Ophthalmol 1980; 64: 863-866.
28. Abramov I, Hainline L, Tukel J, Lemerise E, Smith H, Gordon J, Petry S. Rocket-slip psychophysics, assessing visual function in young children. Invest Ophthalmol Vis Sci 1984; 25: 1307-1315.
29. Corwin TJ, Richman JE. Three clinical tests of the spatial contrast sensitivity function. A comparison. Am J Optom Physiol Optics 1986; 63: 413-418.
30. Atkinson J, Braddick O. New techniques for assessing vision in infants. Child Care Hlth Dev 1979; 5: 389-398.

31. Arden GB. The importance of measuring contrast sensitivity in cases of visual disturbance. Br J Ophthalmol 1978; 62: 198-209.
32. McCall RB. Fundamental statistics for the behavioural sciences. Fourth edn, Ch 4; Measures of relative standing. Percentiles. 70-73 London, Toronto, Sydney: Harcourt, Brace and Javanovich, 1986.
33. Fitzgerald BA. Contrast sensitivity normals for 325 children aged 6 to 12 years using the Vistech system. Submitted to Am J Paed Ophthalmol Strabismus, 1989.
34. Rogers GL, Bremer DL, Leguire LE. Contrast sensitivity in normal children with the Vistech method. J Paed Opthalmol Strabismus 1987; 24: 216-219.
35. Brown VA, Woodhouse JM. Assessment of techniques for measuring contrast sensitivity in children. Ophthalmol Physiol Opt 1986; 6: 165-170.
36. Yates JT, Harrison HM, O'Connor PS, Ballentine C. Contrast sensitivity; characteristics of a large young adult population. Am J Optom Physiol Optics 1987; 64: 519-527.